Relationship between Formation of PCDDs/Fs and Control of CO and HCl Levels in Flue Gas and Gas Temperatures in a Municipal Waste Incinerator

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Abstract

The control of PCDDs/Fs formation was investigated in a municipal waste incinerator equipped with the electrostatic precipitator (EP). The simultaneous control of the CO and the HCl concentration levels and the gas temperature proved very effective in the control of PCDDs/Fs formation, reducing the concentration of PCDDs/Fs in flue gas at the EP outlet to 0.2 ng/Nm^3 as 2,3,7,8-T_4CDD when they were evaluated by the international toxicity equivalent factors.

Keywords

Municipal waste incinerator, PCDDs, PCDFs, Control, Carbon monoxide, Hydrogen chloride, Gas temperature, Dust, Electrostatic precipitator

Introduction

As in Japan, in order to remove dust in the flue gas the great majority of municipal waste incinerators (MWI) are equipped with an electrostatic precipitator (EP) in which PCDDs and PCDFs (PCDDs/Fs) are probably generated from precursors in the flue gas, it is of urgent necessity to make efforts for the control of PCDDs/Fs formation in the incinerators. The parameters of the control of PCDDS/Fs formation have been known to be CO and HCl levels in the flue gas and temperatures of the flue gas passing through the EP. We have already found effects of respective control of CO[1] and HCl levels[2] on the PCDDs/Fs formation as presented at DIOXIN '88.
The object of this investigation was to find the effect of combined control of CO and HCl levels in the flue gas and the flue gas temperature in an incinerator equipped with an EP.

Experimental

Incinerator
The MWI used in this investigation was of a stoker type manufactured by TAKUMA CO., LTD., Japan and gas quenching and HCl removal systems were provided before the EP in the process of flue gas flow. The flow sheet of the MWI system is shown in Fig. 1.

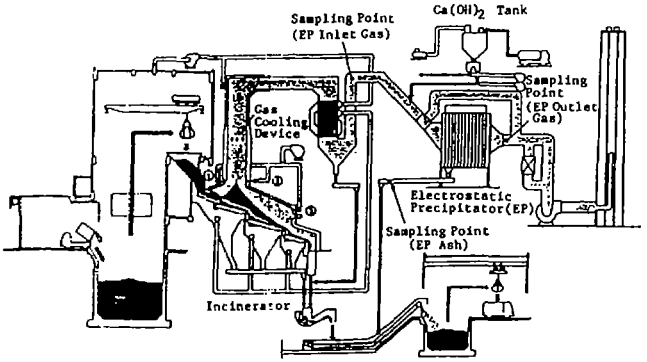

Fig. 1 Flow Sheet of Municipal Waste Incinerator

Sampling

Flue gas samples in the EP inlet and outlet were simultaneously collected at the points shown in Fig. 1. Using a sampler system as shown in Fig. 2, PCDDs/Fs in gas and dust were separately collected. Ash samples were collected from the conveyor of the EP.

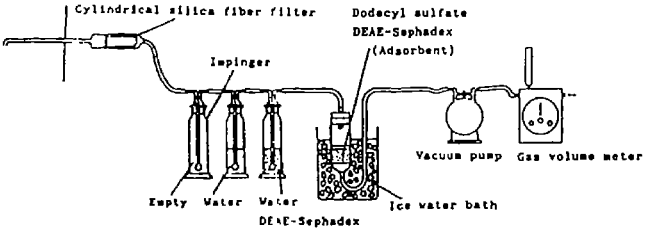

Fig. 2 Gas Sampler System

Analytical Procedure

PCDDs/Fs in the gas and the dust in the gas samples and in the EP ash were analyzed in much the same procedures as we have previously reported[1, 2].

Results and Discussion

Flue Gas Temperatures at EP Inlet and CO and HCl Concentration Levels at EP Outlet

Table I shows the flue gas temperatures at the EP inlet and concentration levels of CO and HCl in the EP outlet gas.

The gas temperatures were well controlled at three average temperatures by water spraying of the gas cooling equipment. In exp. 1-9, CO concentration levels were controlled at low levels extremely well by introducing secondary air to the furnace at the points (1), (2) and (3) shown in Fig. 1, whereas in exp. 10, introduction of secondary air at point (2) was terminated and CO levels much higher than in exp. 1-9.

The concentration levels of HCl in the gas introduced to the EP were controlled to three average concentrations by injecting calcium hydroxide into the flue gas before the EP.

Table I Average Gas Temperatures at EP Inlet and Average CO and HCl Concentration Levels

Exp. No.	Gas Temperature (°C)	CO concentration (ppm)	HCl concentration (ppm)
1	200	4.8	35 (L)
2	200	10.6	138 (M)
3	200	7.7	217 (H)
4	240	3.3	93 (L)
5	240	4.1	177 (M)
6	240	6.4	289 (H)
7	300	2.9	88 (L)
8	300	4.3	169 (M)
9	300	4.0	312 (H)
10	300	202	251 (H)

Concentration of Dust in EP Inlet Gas, Injected Amounts of Calcium Hydroxide, Formed Amounts of EP Ash and Gas Volumes

As dust in the EP inlet gas was sampled at a point before the place where calcium hydroxide was injected, high concentration of the dust in the gas indicated imperfect combustion in the furnace (Table II). In experiments at low CO levels, formed amounts of EP ash increased proportionally to injected amounts of calcium hydroxide. Amounts of the EP ash formed in the EP at the high CO levels were higher than those at the low CO levels. This phenomenon would appear to result from the increase of carbon formed by imperfect combustion in the furnace.

Table II Amounts of Dust in EP Inlet Gas, Injected Amounts of Calcium Hydroxide, Formed Amounts of EP Ash and Gas Volumes

Exp. No.	Dust in EP Inlet Gas (g/Nm^3)	Injected $Ca(OH)_2$ (g/Nm^3)	Formed EP Ash (g/Nm^3)	Gas Volume at EP Outlet (Nm^3/hr)
1	1.28	4.74	6.21	25189
2	1.21	1.64	3.04	26667
3	1.26	0.21	2.01	24085
4	1.52	4.56	6.36	26182
5	1.25	1.72	3.25	25584
6	1.27	0.20	1.84	25589
7	1.30	4.57	6.07	25336
8	1.26	1.67	3.21	26193
9	1.49	0.18	2.13	26720
10	1.51	0.60	3.07	23783

PCDDs/Fs Concentrations in EP Inlet Gas

Fig. 3 shows PCDDs/Fs concentration levels in the EP inlet gas in all the experiments. The majority of PCDDs/Fs in the gas were observed in the dust.

1) Relationship between PCDDs/Fs levels and gas temperatures: In experiments with controlled CO levels, PCDDs/Fs in the gas showed higher concentration levels when the gas temperatures were remained high. PCDDs/Fs were formed from the precursors in the flue gas in the process of flow from the furnace to the gas sampling point just before the place where calcium hydroxide was injected. Quenching the gas by water spray to decrease the gas temperature effectively decreased the PCDDs/Fs formation in the gas.

2) Relationship between PCDDs/Fs levels and CO levels: PCDDs/Fs levels in the gas at the high CO levels were much higher than those at the low CO levels. It is therefore reasonable to assume that PCDDs/Fs were formed more under imperfect combustion in the furnace.

3) Relationship between PCDDs/Fs levels and HCl levels: At the low CO levels, there were no great difference in PCDDs/Fs concentrations in the gas with different HCl levels. Therefore, before the EP the HCl levels in the gas would be not related to the PCDDs/Fs formation directly. In the process of the gas flow from the furnace to the EP, the temperature of the gas was more closely related to the formation of PCDDs/Fs than HCl levels in the gas.

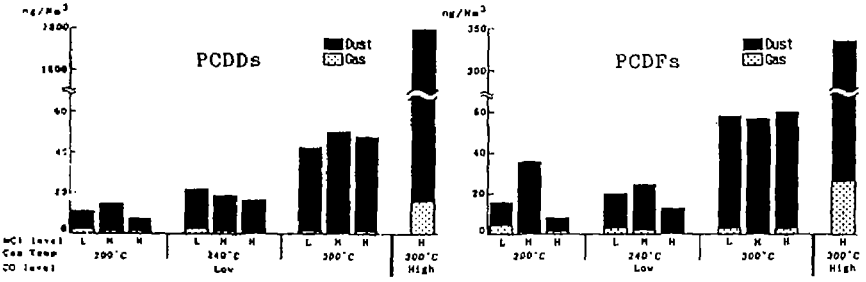

Fig. 3 PCDDs/Fs Concentrations in EP Inlet Gas

PCDDs/Fs Concentrations in EP ash

Fig.4 shows PCDDs/Fs concentrations in the EP ash samples. The higher the gas temperatures and the HCl levels in the gas (except for a combination of the lowest HCl level and the gas temperature of 240°C) were, the more the PCDDs/Fs levels tended to increase. In the series of similar temperatures, the formation tended to increase in the presence of HCl at higher levels.

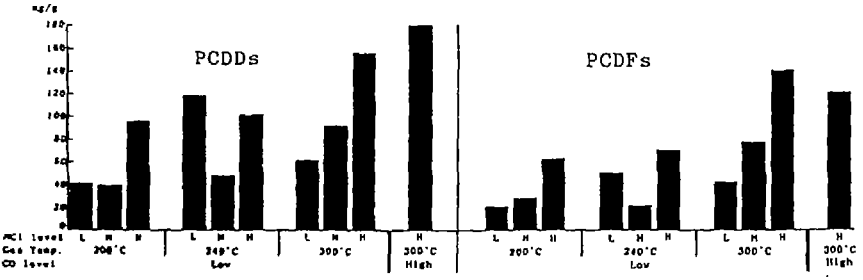

Fig. 4 PCDDs/Fs Concentrations in EP Ash

PCDDs/Fs Concentration in EP Outlet Gas

Fig. 5 shows PCDDs/Fs concentrations in the EP outlet gas in all the experiments.

In every experiment, PCDDs/Fs concentrations in the EP outlet gas were lower than those in the corresponding EP inlet gas, and the majority of PCDDs/Fs in the gas samples were observed in the gas contrary to those in the EP inlet gas.

1) Relationship between PCDDs/Fs concentrations and gas temperatures: PCDDs/Fs concentrations in the EP outlet gas increased when the gas temporatures remained higher for similar HCl levels.

2) Relationship between PCDDs/Fs concentrations and CO levels: PCDDs/Fs concentrations in the gas at the high CO level were higher than those at low CO levels controlled by introducing the secondary air into the furnace at the point (2).

3) Relationship between PCDDs/Fs concentrations and HCl levels: In the experiments at the highest gas temperature and at the low CO levels, the PCDDs/Fs levels tended to increase with higher HCl levels in the gas. The PCDDs/Fs concentrations at the lowest HCl concentration when the gas temperature were at 200 and 240°C showed higher levels than at other HCl levels.

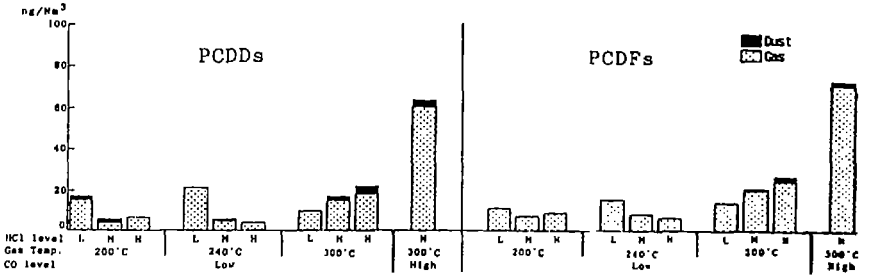

Fig. 5 PCDDs/Fs Concentrations in EP Outlet Gas

Formation Behaviors of PCDDs/Fs

PCDDs/Fs concentrations in the EP inlet gas (1) and in the EP (2) are showing Fig. 6. The latter concentrations were expressed as the sum of the PCDDs/Fs concentrations in the EP outlet gas and those in the EP ash converted per Nm^3 of the flue gas.

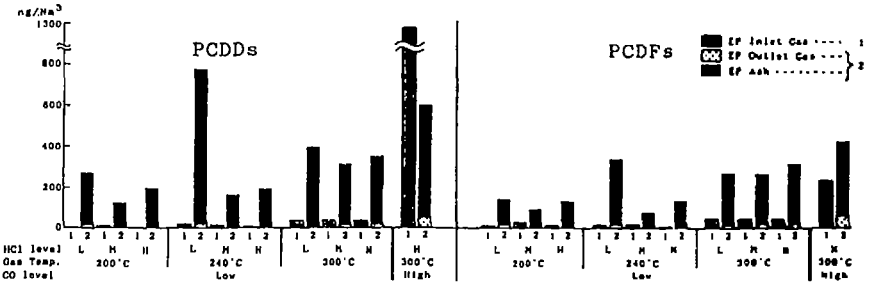

Fig. 6 PCDDs/Fs Formation before and in EP

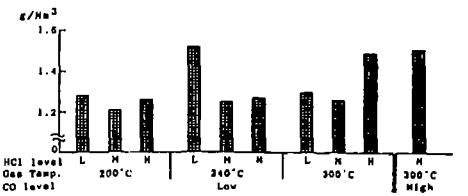

Fig. 7 Amounts of Dust in EP Inlet Gas

In every experiment at the low CO levels, the total concentrations of PCDDs/Fs in the EP was always much higher than in the EP inlet gas, and the majority of PCDDs/Fs in the EP were contained in the EP ash, indicating that the major PCDDs/Fs were formed in the EP from precursors of PCDDs/Fs in flue gas and then adsorbed onto particulates of fly ash.
At the high CO levels, the PCDDs/Fs concentrations formed at high HCl levels and at 300°C of flue gas temperature were much higher than those formed at similar HCl levels and gas temperature in the experiments at the low CO levels.
The PCDDs/Fs concentration levels in the EP were closely related to the amount of dust in the EP inlet gas before the injection of calcium hydroxide as shown in Figs. 6 and 7. Since there were large amounts of precursors of PCDDs/Fs from imperfect combustion in the gas where dust levels in the gas were high, PCDDs/Fs would be formed in proportion to the amount of the dust. If the bag filter had been used to remove the dust in the gas in place of an EP, the PCDDs/Fs concentrations in the outlet gas would show levels below those of the gaseous PCDDs/Fs in the inlet gas.
The first of important factors to control PCDDs/Fs levels in the flue gas discharged from the stack is to keep the CO levels continuously low during combustion by effective introduction of secondary air, resulting in decreased formation of PCDDs/Fs precursors. The second is to lower gas temperature as soon as possible in the process of gas flow and thereby the formation of PCDDs/Fs from precursors will be controlled and the third is to remove the dust in the gas by the bag filter after injection of calcium hydroxide. When an EP is used to remove fly ash, it will be necessary to lower flue gas temperature and HCl levels in the EP to control PCDDs/Fs formation in the EP.

Toxicological Evaluation of PCDDs/Fs in Flue Gas

Based on the international toxicity equivalent factors, the concentrations of 2,3,7,8-substituted PCDDs/Fs in the EP outlet gas were converted to those of T_4CDD as shown in Fig. 8. PCDDs/Fs in the flue gas at the EP outlet when the gas temperatures were at 200℃ and 240℃ at the low CO levels showed the concentration level lower than 0.5 ng/Nm^3 as 2,3,7,8-T_4CDD and the lowest concentration was about 0.2 ng/Nm^3 when the formation in the gas were well controlled.

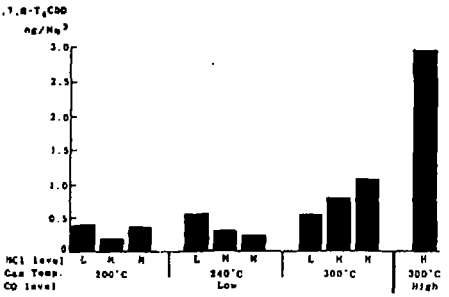

Fig. 8 Concentrations of PCDDs/Fs Converted to 2,3,7,8-T_4CDD Toxicity in Flue Gas at EP Outlet

References

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